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EQUIPMENT PERFORMANCE REPORT FOR THE DRIFTING ACOUSTIC SPAR BUOY RECORDER (DASBR)

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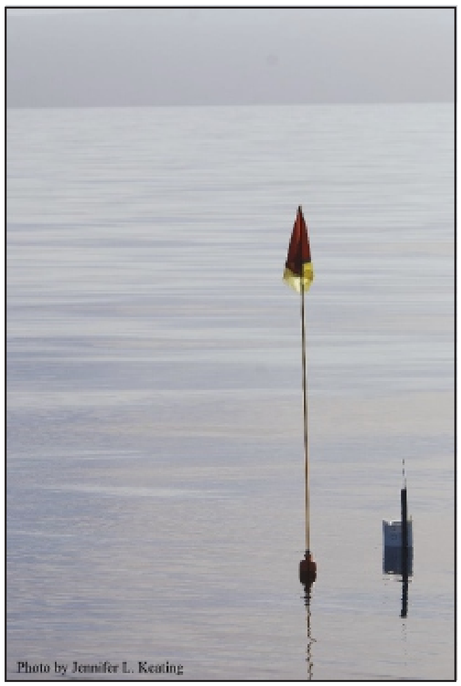

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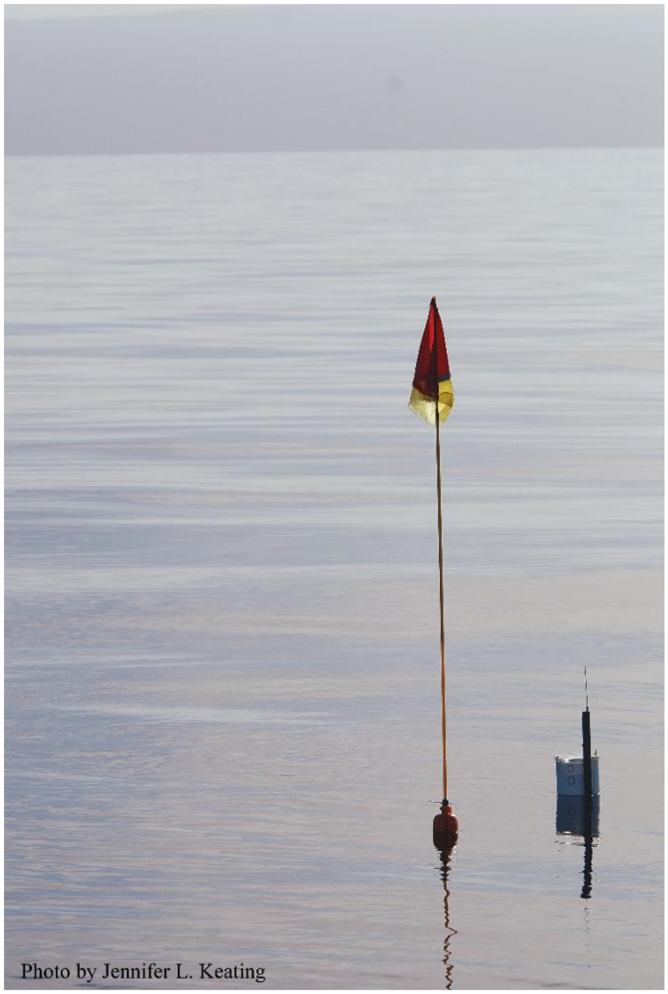

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1. INTRODUCTION

The Drifting Acoustic Spar Buoy Recorder (or DASBR) is an autonomous Passive Acoustic Monitoring (PAM) system developed at the Southwest Fisheries Science Center (SWFSC) to provide a practical, low-cost option for collecting high-quality marine acoustic data. Most autonomous recording systems (such as Cornell's Pop-ups and SIO's HARPS) are bottom-mounted and therefore limited to shelf and slope waters. Fixed moorings in deep pelagic waters are generally too expensive for common use. Hydrophone arrays towed behind research vessels are often used to acoustically detect odontocetes in deeper waters, but they are not ideal. Ship time for towed array surveys is expensive, while ship and water flow noise prevent the collection of ambient noise data using towed arrays. Drifting recording units, such as DASBRs, are not limited to shallow waters, can record deep within the water column, and are isolated from ship noise and flow noise.

Here we present the results of three DASBR field tests including two Passive Acoustic Sea Trials (PAST 2013 & PAST 2014) and the 2014 NOAA *R/V Lasker* shakedown mission trial. We discuss bioacoustic detections of marine mammals and alterations to the original design that were required to prepare the DASBRs for subsequent long-term deployments.

1.1 DASBR Construction

The DASBR unit is designed as a PVC spar buoy (Figures 1 and 2) containing a Wildlife Acoustics[1] Song Meter 2 Bat (SM2BAT+) ultrasonic recorder with a GPS option. The 1.4-m spar buoy is constructed to survive vessel collisions and poses no hazards to navigation. An array of two hydrophones separated by 2m is suspended 100m below the buoy (to avoid surface noise but still allow detection of faint surface reflections from echolocation clicks). A 1 kg anchor and additional lead weights (~1.8 kg) are suspended below the hydrophone array to maintain a vertical orientation and prevent the unit from drifting ashore. Stereo sounds are recorded (16-bits/channel @ 192 ksamples/sec) on flash memory using a duty cycle based on the anticipated deployment time. Hydrophone pre-amps flatten the noise spectrum and allow >70 dB of dynamic range over the entire sound spectrum (10 Hz to 96 kHz). Hydrophone depth (from a pressure transducer in the hydrophone package), surface temperature (inside the buoy), and GPS position are recorded once per sound file. Record times (file lengths) and duty cycles are programmable on the SM2BAT+ recorder. Recovery is facilitated by a low-cost satellite locator which provides at least one location per day and a VHF radio beacon. A complete list of parts used to build the 2013/14 version of the DASBR is given in Appendix A.

1.2 Hydrophone Arrays

Each array includes two hydrophones and a depth (pressure transducer) sensor. The hydrophones are 50cm (upper) and 250 cm (lower) from the top of a castor-oil-filled polyurethane tube with the

[1] Mention of brand names in this report does not imply endorsement by NOAA or the U.S. Government.

depth sensor at the bottom, 300cm from the top. The DASBRs were constructed using several different configurations of HTI-96-min, HTI-92-WB, and Reson TC4013 hydrophone elements (Tables

Table *1*). The internal pre-amp gain settings for the HTI-96-min and HTI-92-WB were selected to maximize the DASBR's potential to capture low frequency baleen whale vocalizations. Specific settings include:

<u>HTI-96-min</u>:	Internal pre-amp gain:	40dB w/ 10 Hz high-pass filter
	Flat frequency response:	2 Hz – 30 kHz.
	Sensitivity:	-160 dB re: 1V / µPa.
	Self-noise spectral levels:	54 dB re: 1 µPa/√Hz @ 10 Hz, 42 dB re: 1 µPa/√Hz @ 100 Hz, 42 dB re: 1 µPa/√Hz @ 1000 Hz.
<u>HTI-92-WB</u>:	Internal pre-amp gain:	20dB w/ 10 Hz high-pass filter
	Flat frequency response:	2 Hz – 50 kHz.
	Sensitivity:	-158 dB re: 1V µPa.
	Self-noise spectral levels:	43 dB re: 1 µPa/√Hz @ 100 Hz, 27 dB re: 1 µPa/√Hz @ 1,000 Hz, 15 dB re: 1 µPa/√Hz @ 10,000 Hz, 12 dB re: 1 µPa/√Hz @ 20,000 Hz, 10 dB re: 1 µPa/√Hz @ 50,000 Hz.
<u>Reson 4013</u>:	External pre-amp gain:	40dB w/ 1 kHz high-pass filter
	Flat frequency response:	1 Hz – 100 kHz.
	Sensitivity:	-211 dB ±3 dB re: 1V/µPa.
	Self-noise spectral levels:	76 dB re: 1 µPa/√Hz @ 10 Hz, 64 dB re: 1 µPa/√Hz @ 100 Hz, 56 dB re: 1 µPa/√Hz @ 1,000 Hz, 51 dB re: 1 µPa/√Hz @ 10,000 Hz.

1.3 Satellite Locators

The DASBR can accommodate two satellite locators in the upper region of the spar buoy. Table 2 lists the types of locators used. Whenever possible, two satellite locators were used in each DASBR.

2. METHODS

DASBRs were tested on three sea trials. The first trial, PAST 2013, was conducted over 3 weeks in November, 2013. This was the first time DASBRs were deployed and left unattended in the field. This deployment was to test the DASBR design and be a model for longer deployments assessing cetacean distribution and abundance. During PAST 2014 and the shakedown trial, in March and May of 2014, respectively, two DASBRs were deployed for less than 24 hours to test modifications that were made to improve DASBR performance. Deployment and retrieval information for the three sea trials is given in Table 3.

For ease of transport, DASBRs can be disassembled into more manageable parts. Therefore, each DASBR requires some assembly before it is deployed. Figure 3 shows a checklist for DASBR deployment. The SM2BAT+ is attached to the power supply and programmed prior to deployment. From the screen interface the following settings can be programmed: sample rate, recording format, number of channels (stereo or mono), filename prefix and a duty cycle. The SM2BAT+ has external hardware gain and filter settings that can be programmed before a deployment. For more information on the SM2BAT+ and how it is programmed, please review the manual (2011, Wildlife Acoustics, Inc.).

2.1 PAST 2013

The primary objective of PAST 2013 was to test a new survey design using DASBRs in point-transect surveys of cetaceans, specifically, beaked whales. Secondary objectives included a localization test of the towed hydrophone array, and testing of various acoustic gear. All secondary testing occurred during down-time between deployment and retrieval of DASBRs and will not be discussed in this report. Both legs of PAST 2013 were conducted on a 65' fishing vessel, the F/V *Outer Limits*, in November, 2013.

On Leg 1 (November 9-14, 2013) five DASBR units were deployed twice in the Catalina Basin between San Clemente and Santa Catalina Islands, identified as DASBR 0-4. The first deployment took place in the afternoon on November 9th, local time. All five DASBRs were deployed along a north-south orientated track line on the east side of the Catalina Basin. They were retrieved on the morning of November 12th and were re-deployed that afternoon along an east-west line in the west end of the Basin. The SM2BAT+ gain and filter settings are given in Table 3.

On Leg 2 (November 17-21, 2013) DASBR4 was retrieved in the evening of November 17th. The remaining four units were retrieved in the morning on November 18th, and all five units were deployed again that afternoon. For the third deployment, DASBRs 0, 1, 2, and 4 were deployed in a 1 nmi square formation at the north side of the Basin. Artificial whistles and clicks were broadcast from a playback device (Aaron Thode, Scripps Institute of Oceanography) to test localization capabilities of an array of DASBRs. An independent recording device obtained from Aaron Thode was deployed at the center of the square formation and recorded at a sampling rate of 100 kHz. Results from that device will not be discussed in this report. At 36 different locations in and around the DASBR array the playback device was lowered to 33m (Appendix A). Each station consisted of 5-15 minutes of alternating clicks and whistles. The square formation was deformed by differential buoy drift, therefore DASBR2 was retrieved on November 20th and re-deployed the same morning to replicate the approximate original square formation.

DASBR3, which had not collected consistent GPS data during the first and second deployments, was also deployed on November 17th, but in the southern region of the Catalina Basin. It was not closely associated with the square array. All DASBRs were retrieved in the morning on November 21st before returning to port.

2.2 PAST 2014

On March 28th, 2014 the 65' vessel M/V *Pacific Voyager* departed Seaforth Landing in San Diego to field test acoustic equipment, including two units: DASBR2 and DASBR3. For this sea trial we transited to deep offshore waters outside shipping lanes. DASBRs were deployed and retrieved on the same day, with each deployment lasting approximately 5-6 hours.

For this deployment, the upper hydrophone element in DASBR3 was potted in Smooth-On Clear Flex® 95 polyurethane. DASBR2 was deployed unchanged as a control. A different recording schedule, introducing a 30 second duty cycle per 5 minutes of recording, was employed during this deployment. Aaron Thode's playback device from SIO was also deployed during this sea trial in proximity of the DASBR deployment locations. To improve recordings of baleen whale vocalizations on PAST 2014, the SM2BAT+ high-pass filter on the lower hydrophone was decreased to 3Hz (Table 3).

2.3 Shakedown Mission Sea Trial

The NOAA Ship *Reuben Lasker* is a new 208-m scientific fisheries research vessel which will support fish, marine mammal and turtle surveys off the U.S. west coast and in the eastern tropical Pacific Ocean. Hydrophone arrays were tested in conjunction with DASBR2 and DASBR3 deployments on leg 4 (May 18-22) of a series of *Lasker* shakedown cruises. DASBRs were deployed on May 20th and retrieved on May 21st near Santa Catalina Island.

The DASBR3 hydrophone array was rebuilt with new HTI-96-min elements (internal preamp: gain = 20 dB, high-pass filter = 100 Hz). Signals were further amplified with a secondary, differential pre-amp with a gain of 40 dB and a high-pass filter at 159 Hz. The SM2BAT+ gain was reduced to 0 dB on both channels to accommodate the higher total gain in the array.

2.4 Data processing

Detailed analyses were conducted only for the longer (PAST 2013) deployments. Other deployments were only used to evaluate improvements in DASBR design.

2.4.1 Maps

Maps of DASBR trajectories were generated for each PAST 2013 deployment. All maps were created in RStudio ver 0.98.953 using the ggplot and Rgooglemaps packages (Wickham, 2009; Loecher and Roplins, 2015). The DASBRs collected GPS coordinates every time a new sound file was generated.

2.4.2 Long-term Spectral Averaging

Long-term Spectral Averages (LTSAs) were generated for each PAST 2013 deployment to identify times of high bioacoustic activity. LTSAs were created using PAMGuard (Gillespie, *et. al*, 2008) with 5 seconds per sample/200 Hz bin size. LTSA images were exported from PAMGuard at 10 pixels per hour. LTSA images were then imported into ImageJ v1.48 (Rasband, 1997-2014) where a pixel intensity profile was generated to quantify times of high odontocete (mostly delphinid) bioacoustic activity (Figure 4). Bioacoustic activity was inferred if the average of the unscaled pixel intensities was over a critical threshold in the frequency range of 5-96 kHz.

2.4.3 Click Detector

Automated analysis of odontocete clicks in the PAST 2013 DASBR recordings was performed in PAMGuard. The PAMGuard click classifier measures features from each echolocation click and classifies it based on user-defined parameters. The click classifiers used are outlined in Keating and Barlow (2013). Since the top hydrophone had more problems with missing data (drop-outs, see Results section) detections and classifications were based on data from the lower hydrophone.

2.4.4 Low Frequency Hand-Browsing

A trained analyst manually reviewed spectrograms of sound files from each PAST 2013 deployment to identify acoustic detections from baleen whales, such as minke or humpback whales, using Raven Pro v1.5 software (Charif et. al, 2010). Due to data quality issues on the upper hydrophone, data from only the lower hydrophone was viewed between 0-5000Hz, FFT=4092, Overlap=85%. If a candidate signal was detected it was classified by the analyst using key feature measurements (e.g., start and end time, frequency band, peak frequency).

2.4.5 Drift Speed, Depth, and Temperature plots

For PAST 2013 deployments, time series of hydrophone depth, surface temperature and drift speeds were plotted (Appendix C, Appendix D, andAppendix E for deployments 1, 2, and 3, respectively). Drift speeds were calculated by dividing the great-circle distance the DASBR traveled by the time elapsed between recorded sound files.

3. RESULTS

3.1 Troubleshooting

There were two major data quality issues with the data from PAST 2013: drop-outs and scheduling errors. These issues were investigated and resolved during the PAST 2014 and shakedown trials. Through all three sea trials, we fine-tuned the placement of the satellite locators and the hydrophones used in the DASBR arrays.

3.1.1 Drop-outs

Gaps in acoustic data, or drop-outs, occurred throughout all PAST 2013 deployments on channels recorded with a HTI-96-min hydrophone element. Though drop-outs were more frequent on the upper hydrophone, they were also observed on lower). The dropouts were not correlated with bioacoustics activity (Figure 5 andFigure *6*), but rather caused by saturating levels of low-frequency pressure changes, presumably from passing waves.

As mentioned previously, the initial internal high-pass filter of the HTI-96-min hydrophones (10 Hz) was chosen to maximize the DASBR's potential to capture low frequency baleen whale vocalizations. However, this value coupled with a gain of 40dB made the hydrophone highly sensitive to pressure changes. Two approaches were taken to reduce drop-outs from low-frequency pressure waves: 1) with the same internal pre-amp gain and filter settings (40 dB and 10 Hz, respectively) the hydrophone was potted in Smooth-On Clear Flex® 95 polyurethane, and 2) a hydrophone array was rebuilt with new HTI-96-min elements with different gain and filter settings (20dB and 100Hz, respectively). These approaches were tested on the PAST 2014 and shakedown trial, respectively.

Potting the hydrophones in a hard plastic during PAST 2014, rather than suspending them in oil, was found to reduce their sensitivity to changes in pressure and dramatically decrease the number of drop-outs found on DASBR recordings. However, drop-outs were still present. For the shakedown trial, using the new HTI hydrophones removed unwanted drop-outs during data collection.

3.1.2 Scheduling Error

For PAST 2013, each DASBR was programed to continuously record by generating consecutive 2-minute sound files. Post-cruise analysis found this programming schedule removed a segment of acoustic data lasting a few milliseconds to 2-3 full seconds from the beginning of each sound file. It was discovered that the SM2BAT+ needs to have a duty cycle between each recording file to prevent data loss.

Wildlife Acoustics provided technical assistance to help diagnose the timing issue. Before recording initializes, the SM2BAT+ scans its drives to ensure that there is enough room for the file it is programed to generate. If the DASBR was scheduled to record for 1 minute at 10AM, it would start scanning for available disk space *before* 10AM so it could start recording at exactly 10:00:00.000. The more full the disk, the more time it takes to complete the scan. Once the scan is complete the appropriate amount of disk space is allocated for the scheduled recording. After the scheduled period of recording, the SM2BAT+ system takes additional time to close and save that file. In some cases, the SM2BAT+ will randomly generate a short or 0 value sound file, wait an unpredictable amount of time (we've seen this range from 4-12 minutes), reset itself, and then start the process over again.

These timing errors prevented localization on experimental playback signals and vocalizing animals in the study area using time-of-arrival differences between DASBR units. Therefore, localization was not tested using the PAST 2013 data.

To fix this issue, we've introduced a duty cycle to our recording schedule. A pause of at least 30 seconds for four to five minute sound files gives the recorder enough time between files to write the preceding file to the disk and scan for available disk space for the next file. This was tested during PAST 2014 and was found to correct the data loss issue. Using this method, less environmental data was collected, but recordings were mostly continuous without the risk of unintentionally losing an unknown amount of data. Additionally, when the DASBRs are deployed for months during long marine mammal surveys, a duty cycle may be preferred to prolong battery life and efficiently use available storage space.

3.1.3 Satellite Locators

Satellite locations were not reliably received on all DASBR deployments during PAST 2013, located within the top 12 inches of the housing. On subsequent deployments, the location of the satellite transmitters was adjusted to be as high as possible within the DASBR buoy housing, next to the lid. This readjustment provided more reliable transmissions.

3.1.4 Hydrophone selection

The HTI-96-min hydrophone provided very good, low-noise recordings once the problem with dropouts was resolved. One aim of the DASBRs is to measure ambient noise. Self-noise levels below 1 kHz are too high for the Reson TC4013 hydrophone for reliable use. Self-noise levels in the HTI-96-WB were lower than the HTI-96-min, but the cost was four times higher for that hydrophone.

3.2 PAST 2013 Deployments

Results from the preliminary biological analysis from the three PAST 2013 DASBR deployments.

3.2.1 Deployment 1

For deployment 1 (Figure 7), DASBR4 failed to record any data except GPS tracking. DASBR0 failed to record depth data, and DASBR3 had missing GPS data.

LTSAs were generated for each DASBR which successfully collected acoustic data. The lower frequencies (0-5kHz) had consistent noise levels that are not related to bioacoustics activities. Therefore, when measuring bioacoustic activity, everything below 5 kHz was removed. Variation in noise levels from 5-96 kHz were mostly due to delphinid bioacoustic activity, present for 35% of the deployment (Table 4). No other echolocation clicks or baleen whales were detected.

3.2.2 Deployment 2

Due to equipment failure in deployment 2 (Figure 8), DASBR0 only recorded an acoustic signal from November 12th, 21:48:90 – November 15th, 06:57:20 and November 18th, 2:46:15 – 22:18:15 (UTC). The unit failed to record any data outside of that time, and failed to record depth data for the entire deployment. DASBR1 failed to record any data except GPS tracking. DASBR3 failed to record any GPS data.

As with deployment 1, when measuring bioacoustic activity everything below 5 kHz was removed. LTSA biological activity measurement is mostly indicative of delphinid bioacoustic activity, which occurred for 20% of the deployment across all units.

Beaked whale echolocation clicks were recorded on November 13th between 04:49-04:53 UTC (Figure 10). The temporal and spectral characteristics of this click train suggest a Cuvier's beaked whale (peak frequency: 37-42 kHz, IPI: 350-500 ms, Baumann-Pickering et al (2013)). No baleen whales were detected.

3.2.3 Deployment 3 (and 4 for DASBR2)

DASBR0 failed to record depth data for deployment 3 (Figure 9). All other data was successfully collected. As with previous deployments, when measuring bioacoustic activity within the LTSA, everything below 5 kHz was removed. Delphinid bioacoustic activity occurred for 35% of the deployment.

In addition to the delphind clicks detected, there were four beaked whale detections during deployment 3 (Table 5). The first was on November 19th recorded on three DASBR units just after deployment, the strongest on DASBR0. The difference in time of arrival for these signals cannot be accurately calculated due to the previously mentioned scheduling error. There were two beaked whale click trains detected on DASBR2 during deployment 4 on November 21st between 06:00-06:28. The first click train is highly characteristic of a Cuvier's beaked whale. The second was much closer to the 43 kHz beaked whale click train described in Baumann-Pickering et al (2013) (Figure 11). The beaked whale species that produces this BW43 click train type has yet to be identified. No baleen whales were detected.

3.3 PAST 2014 and Shakedown Mission Trials

DASBRs were deployed and retrieved during PAST 2014 without issue. The shakedown trial was the first time DASBRs were deployed from a large research vessel, rather than mid-sized fishing vessels. DASBR2 was intended as a control for comparison to the modified hydrophone in DASBR3. However, due to an unexpectedly rough deployment, the SM2BAT+ daughter board (for high-frequency analog-to-digital conversion) was knocked loose within the DASBR2 spar casing and the unit failed to record any data. DASBR3 worked without issue, and did not suffer from drop-outs. Previously, the hydrophone array was deployed first. However, on a larger vessels the underwater current can pull the array away while the ship has to maintain a minimum speed to be maneuverable. This can lead to a hasty (and rough) deployment of the spar buoy housing. Subsequent, it is recommended that DASBRs are deployed by gently lowering the spar buoy unit first and allowing the hydrophone cable to pay out at a relaxed pace while the vessel travels at 0.5-1 knots. Additional padding was also added within the internal casing to help keep the SM2 board in place.

In addition to odontocetes bioacoustic activity, the new HTI-96-min hydrophones with a higher high-pass filter were still able to record several D-calls from migrating blue whales (Figure 12).

4. DISCUSSION AND CONCULSION

During deployment of the DASBRs during PAST 2013 we recorded dolphin acoustic activity approximately 30% of the time over the three deployments and identified five beaked whale detections. In the day-long deployment during the PAST 2014 and shakedown trial, baleen whales were also recorded, proving that DASBRs are useful for acoustically detecting both odontocetes and mysticetes. These test deployments of the DASBRs were successful not only in recording the mid-water soundscape but also in allowing us to troubleshoot major technological issues.

DASBRs were found to be useful for detecting sounds made by cryptic cetacean species. This is particularly valuable for beaked whales, which are notoriously difficult to see from boats, spend a minimal amount of time at the surface, and make deep, long dives (Barlow et al., 2006; Barlow and Gisiner, 2006). Visual boat transect surveys are limited by external factors which reduce the likelihood of sighting an animal, such as Beaufort sea state and individual observer variance (Barlow et al., 2001; Barlow et al., 2011). While acoustic monitoring of cetaceans is most effective when paired with visual surveys (Širović et al., 2004; Barlow and Taylor, 2005; Rankin et al., 2007), independent passive acoustics is a rapidly expanding monitoring technique (Mellinger, et al., 2007) and has been used successfully for beaked whale population density estimates (Marques, et al., 2009) and uncovering previously unknown beaked whale habitat (Yack et al., 2013). A long-term, large scale deployment of DASBRs could provide valuable information on vocal, low visibility cetacean species and/or populations.

There is also the potential for further investigation about the acoustic behavior of vocal species. During deployment 3 of PAST 2013, two beaked whale click types were recorded within 30 minutes of each other. The first click train possessed characteristics defined as a Cuvier's beaked whale as defined in Zimmer et al. (2005) and Bauman-Pickering et al. (2013). The second click train had a peak frequency (43 kHz) and inter-pulse-interval characteristic of a beaked whale (BW43) that has been described before, but which has not yet been recorded in association with a visual sighting (Bauman-Pickering et al., 2013; Yack et al., 2013). The temporal proximity of the two click types suggests that the BW43 click type may be an additional click type utilized by Cuvier's beaked whale, or the beaked whale species that produces the BW43 click type may associate with Cuvier's beaked whales. Future recordings of beaked whale clicks trains, paired with visual confirmation of species identification, and comparing detections over time are needed to determine the source of the BW43 click type. DASBRs provide a new opportunity to capture vocalizations in remote areas, and therefore can further inform our understanding of cetacean behavior.

All monitoring techniques have drawbacks unique to their design. The issues with DASBRs are inherent to their free-floating nature. DASBRs cannot survey an area with an even distribution as they are subject to currents and wind patterns. Design modifications were considered, although not carried out due to financial cost. There is always the risk of loss if all tracking devices fail or if the unit suffers damage from weather or ship strikes. Data can also be lost due to human error or design failures. During PAST 2013 we had many instances of the GPS, depth and temperature gauges failing to record data. As witnessed during the shakedown trial, a rough deployment can knock loose some of the internal components, causing equipment failure. The revised deployment method has eliminated most of these data loss issues.

However, the advantages of a comparatively cheap, autonomous unit are evident. DASBRs record very clean data with little self-noise, do not bias data collection (e.g., animals avoiding or being attracted to research vessels), are capable of detecting a broad spectrum of animal vocalizations (beaked whales to blue whales), and can reach off-shore waters not accessible by bottom mounted PAM devices. They can provide valuable information on the acoustic ecology of remote marine field locations. As passive acoustics methods are increasingly employed in marine mammal surveys, the DASBR complements previously existing assessment techniques by broadening our understanding of the marine ecosystem.

ACKNOWLEDGEMENTS

We thank the crew of the *Outer Limits*, for their positive, helpful attitude and culinary skills, and Aaron Thode for lending us his playback device. We appreciate the help provided by the scientists on both PAST trials (Jennifer Keating, Shannon Rankin, Don Ljungblad, Jeff Moore, Aly Fleming, Kerri Seger, Eric Keen, Anne Simonis, Eiren Jacobson, Amy Van Cise, Yvonne Barkley, and Alexander Lin). Jeff King and the technology support team at Wildlife Acoustics provided information that helped us understand the scheduling issue. Funding was provided by NOAA's Southwest Fisheries Science Center, NOAA's Acoustic Program, and NOAA's Cooperative Research Program. Thank you to Shannon Rankin, Anne Simonis, and Jeff Moore for their constructive reviews of this memo.

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Tables

Table 1. A list of hydrophone elements and satellite locators in each DASBR unit during PAST 2013 test deployments.

DASBR	0	1	2	3	4
Upper Hydrophone	HTI-96-min	HTI-96-min	HTI-96-min	HTI-96-min	HTI-96-min
Lower Hydrophone	HTI-92-WB	Reson 4013	HTI-96-min	HTI-96-min	HTI-96-min
Satellite Locator 1	Spot Hug	Spot Hug	Spot Hug	DeLorme InReach SE	Spot Hug
Satellite Locator 2	Spot Gen3	Spot Gen3	Spot Gen3	Spot Gen3	Spot Gen3

Table 2. Satellite locators used in the DASBRs during test deployments.

Type	Transmission Effort	Battery Life	Extras
Spot Hug	1 per day	6-9 months from 4 AA batteries.	Has the longest life.
Spot Gen3	1 per hour (can be programed to every 5, 10, 30 or 60 mins)	1 month from 4 AAA batteries.	Has unlimited track mode sending locations every transmission effort.
DeLorme inReach	1 per 4 hours	1 month from 4 D-cell batteries.	Has global tracking coverage based on Iridium system.

Table 3. DASBR deployment and retrieval dates, times, and locations. West longitudes are negative.

Trial	Unit	Deployment Time (GMT)	Deploy Latitude	Deploy Longitude	Retrieval Time (GMT)	Retrieval Latitude	Retrieval Longitude	Gain (dB) upper/lower	Filter (Hz) upper/lower
PAST 2013, Dep1	DASBR0	11/9/2013 10:26:06 PM	32.95427	-118.34949	11/12/2013 7:26:52 PM	32.87189	-118.38149	12/12	180/1000
	DASBR1	11/9/2013 11:02:42 PM	33.02106	-118.35802	11/12/2013 7:10:13 PM	32.89129	-118.37287	12/12	180/1000
	DASBR2	11/9/2013 11:33:57 PM	33.08594	-118.36600	11/12/2013 6:20:53 PM	32.98048	-118.42520	12/12	180/1000
	DASBR3	11/10/2013 12:03:20 AM	33.15298	-118.37524	11/12/2013 5:20:23 PM	33.07993	-118.31808	12/12	180/1000
	DASBR4	11/10/2013 12:33:27 AM	33.21872	-118.38891	11/12/2013 3:54:56 PM	33.16013	-118.31095	12/12	180/1000
PAST 2013, Dep2	DASBR0	11/12/2013 10:05:27 PM	33.12532	-118.60562	11/18/2013 8:38:43 PM	33.06270	-118.54458	12/12	180/1000
	DASBR1	11/12/2013 10:37:04 PM	33.19301	-118.60685	11/18/2013 7:11:15 PM	33.21428	-118.55869	12/12	180/1000
	DASBR2	11/12/2013 11:06:46 PM	33.25764	-118.60526	11/18/2013 7:58:07 PM	33.14310	-118.54782	12/12	180/1000
	DASBR3	11/12/2013 11:37:51 PM	33.32589	-118.60644	11/18/2013 7:38:58 PM	33.16701	-118.52583	12/12	180/1000
	DASBR4	11/13/2013 12:09:20 AM	33.39381	-118.60601	11/17/2013 11:59:43 PM	33.44712	-118.60419	12/12	180/1000
PAST 2013, Dep3	DASBR0	11/18/2013 11:24:39 PM	33.23100	-118.41112	11/21/2013 3:23:09 PM	33.20917	-118.50094	12/12	180/1000
	DASBR1	11/18/2013 11:02:38 PM	33.21466	-118.41190	11/21/2013 4:46:42 PM	33.16546	-118.44309	12/12	180/1000
	DASBR2	11/18/2013 11:49:45 PM	33.23021	-118.43324	11/20/2013 3:23:01 PM	33.22201	-118.48783	12/12	180/1000
	DASBR3	11/18/2013 9:31:18 PM	33.05817	-118.42411	11/21/2013 5:57:31 PM	33.06571	-118.26572	12/12	180/1000
	DASBR4	11/18/2013 10:43:48 PM	33.21737	-118.43418	11/21/2013 4:15:09 PM	33.17686	-118.48157	12/12	180/1000
PAST 2013, Dep4	DASBR2	11/20/2013 4:05:01 PM	33.21704	-118.43931	11/21/2013 4:32:34 PM	33.18166	-118.45115	12/12	180/1000
PAST 2014	DASBR2	3/28/2014 3:14:01 PM	32.82991	-117.46682	3/28/2014 8:54:04 PM	32.79661	-117.46268	12/12	180/3
	DASBR3	3/28/2014 3:24:29 PM	32.83455	-117.47617	3/28/2014 8:41:06 PM	32.80468	-117.47221	12/12	180/3
	Playback	3/28/2014 3:37:52 PM	32.84519	-117.49313	3/28/2014 8:36:26 PM	32.80569	-117.47532	N/A	N/A
Shakedown	DASBR2	5/20/2014 8:03:42 PM	33.46476	-118.407	5/21/2014 2:30:39 PM	33.48521	-118.483	0/0	180/3
	DASBR3	5/20/2014 7:56:30 PM	33.46719	-118.414	5/21/2014 2:31:15 PM	33.48498	-118.483	0/0	180/3

Table 4. Number of 6-minute long-term spectral averages (LTSAs) samples during each deployment of PAST 2013 and number and fraction of those with biological activity indicated the presence of cetaceans. DASBR4 failed to record during deployment 1, and DASBR1 failed to record during deployment 2.

		DASBR0	DASBR1	DASBR2	DASBR3	DASBR4	TOTAL
Deployment 1	LTSA samples	685	678	671	655	-	2689
	Number with biological activity	457	146	181	161	-	945
	Percentage	66.7	21.5	27.0	24.6	-	35.1
Deployment 2	LTSA samples	287	-	1409	1406	1205	4307
	Number with biological activity	109	-	300	260	180	849
	Percentage	38.0	-	21.3	18.5	14.9	19.7
Deployment 3	LTSA samples	641	646	649	683	654	3273
	Number with biological activity	282	176	265	219	194	1136
	Percentage	44.0	27.2	40.8	32.1	29.7	34.7

Table 5. Duration and location of the five beaked whale detections recorded on the DASBRs during PAST 2013. One Cuvier's beaked whale was detected on three instruments (Cuvier's BW*). West longitudes are negative.

Classification	Begin Time (UTC)	End Time (UTC)	Latitude	Longitude	DASBR
Cuvier's BW	11/13/2013 4:49:19 AM	11/13/2013 5:07:38 AM	33.26076	-118.60411	DASBR2
Cuvier's BW*	11/19/2013 3:43:57 AM	11/19/2013 3:51:27 AM	33.23216	-118.41208	DASBR0
Cuvier's BW*	11/19/2013 03:39:26 AM	11/19/2013 03:51:28 AM	33.21349	-118.40968	DASBR1
Cuvier's BW*	11/19/2013 03:56:48 AM	11/19/2013 03:57:03 AM	33.21638	-118.42695	DASBR4
Cuvier's BW	11/19/2013 11:30:24 AM	11/19/2013 11:43:02 AM	33.21518	-118.43390	DASBR4
Cuvier's BW	11/21/2013 6:01:55 AM	11/21/2013 6:04:52 AM	33.19764	-118.45840	DASBR2
BW43	11/21/2013 6:16:35 AM	11/21/2013 6:28:12 AM	33.19774	-118.45932	DASBR2

Figures

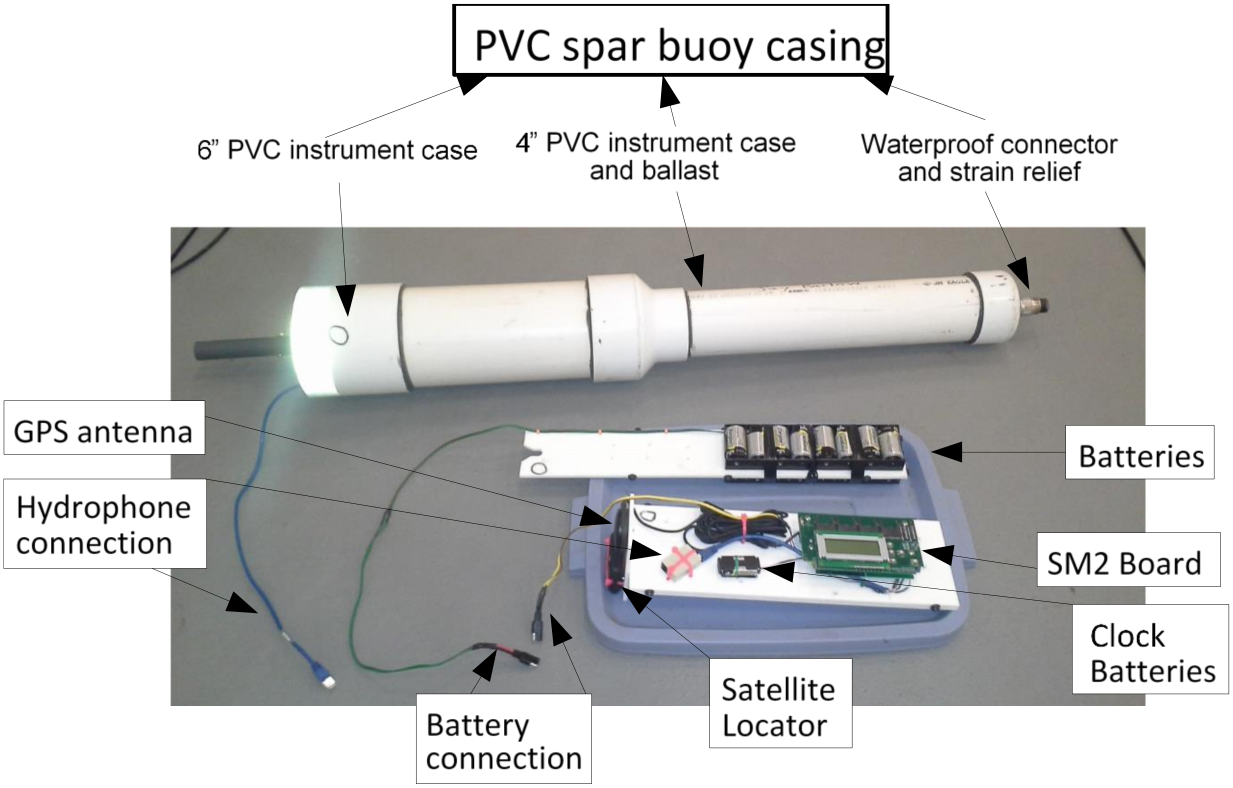


Figure 1. DASBR casing and the internal boards.

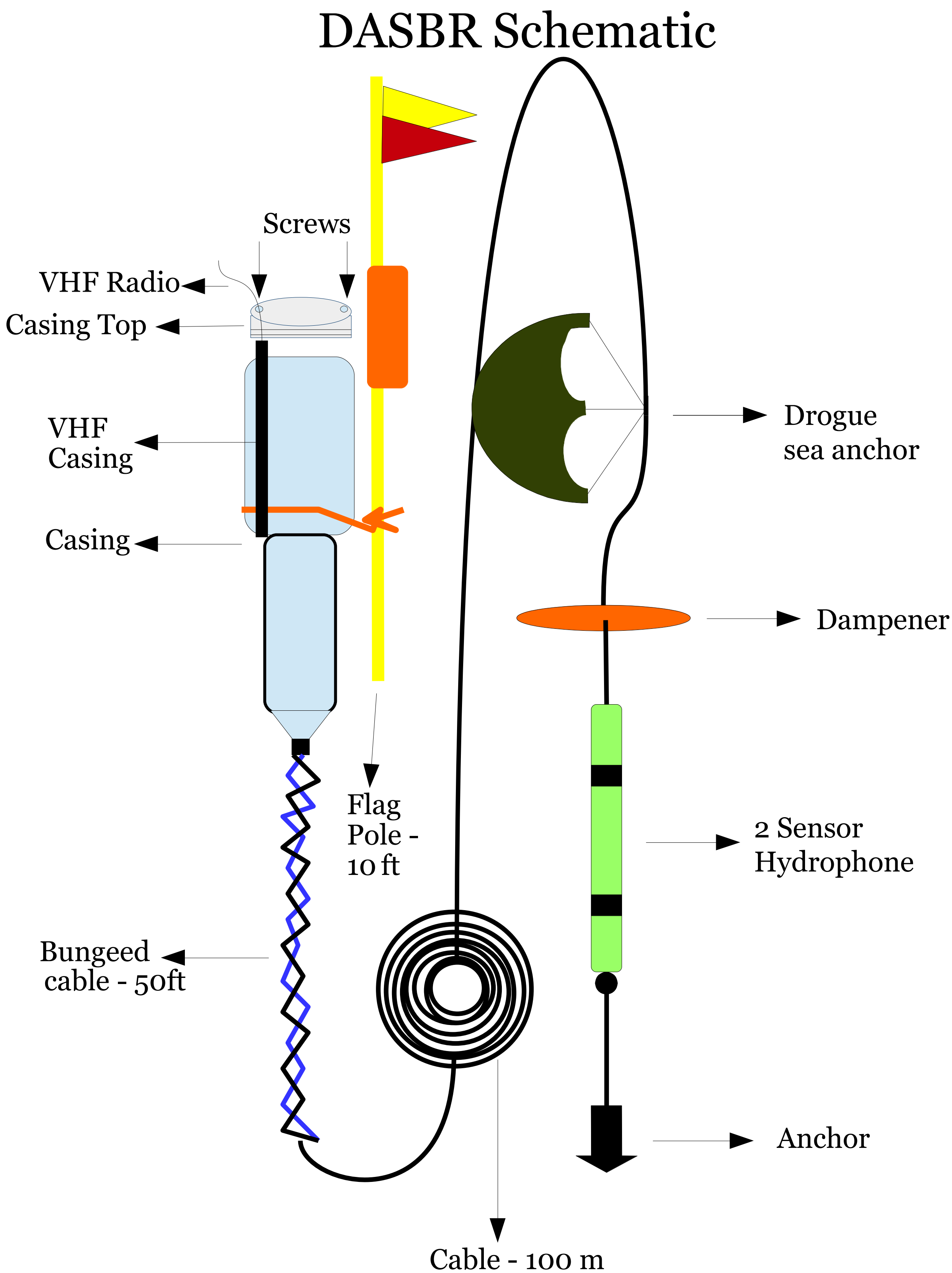


Figure 2. Complete DASBR schematic. Not to scale.

Drifting Acoustic Spar Buoy Recorder (DASBR) Deployment Checklist

DASBR # ___3___ Array #___3___ SD Card #s A_1_ B_2_ C_3_ D_4_

Deployment: 1 YYYYMMDD _20140416_ HHMMSS_143125_ Lat _33.235_ Long_118.345_

Retrieval: 1 YYYYMMDD _20140418_ HHMMSS_163714_ Lat _33.248_ Long_118.483_

Time Zone: GMT / Local

Gain/Filter Settings: Upper _000001010_ Lower _010101010_

Voltage: Starting _6.45_ Ending _5.26_

1st Satellite Locator ___Gen2 - A___
Tracking On? ☒
2nd Satellite Locator ___Hug - 3___
Tracking On? ☒
VHF Radio Tag Frequency ___164.024___
Transmitting OK? ☒
Other Instrument ___DSG -1257___
Device On? ☒

O-ring Clean? ☒
Anchor weight (g)___4___ ☒
Flagpole Attached? ☒

Plugged in:
Batteries to SM2 board? ☒
SM2 board on? ☒
Hydrophone physical? ☒
Hydrophone electronic? ☒

SM2 Settings:
Sample Rate: _192000Hz_
Recording format: _.wav_
Stereo or Mono?
Prefix: ___DASBR3___
Duty Cycle: _5 min on, 1 min off_

Tap Test:
Sample Rate:_48kHz_
Include details here:

Everything okay!

OR

Lower hydrophone had a weak signal and had very static-y feedback.

☒ Recorder on?

Notes:

Checked by: ___JB & ETG___

Page # _4_

Figure 3. Example DASBR deployment checklist form.

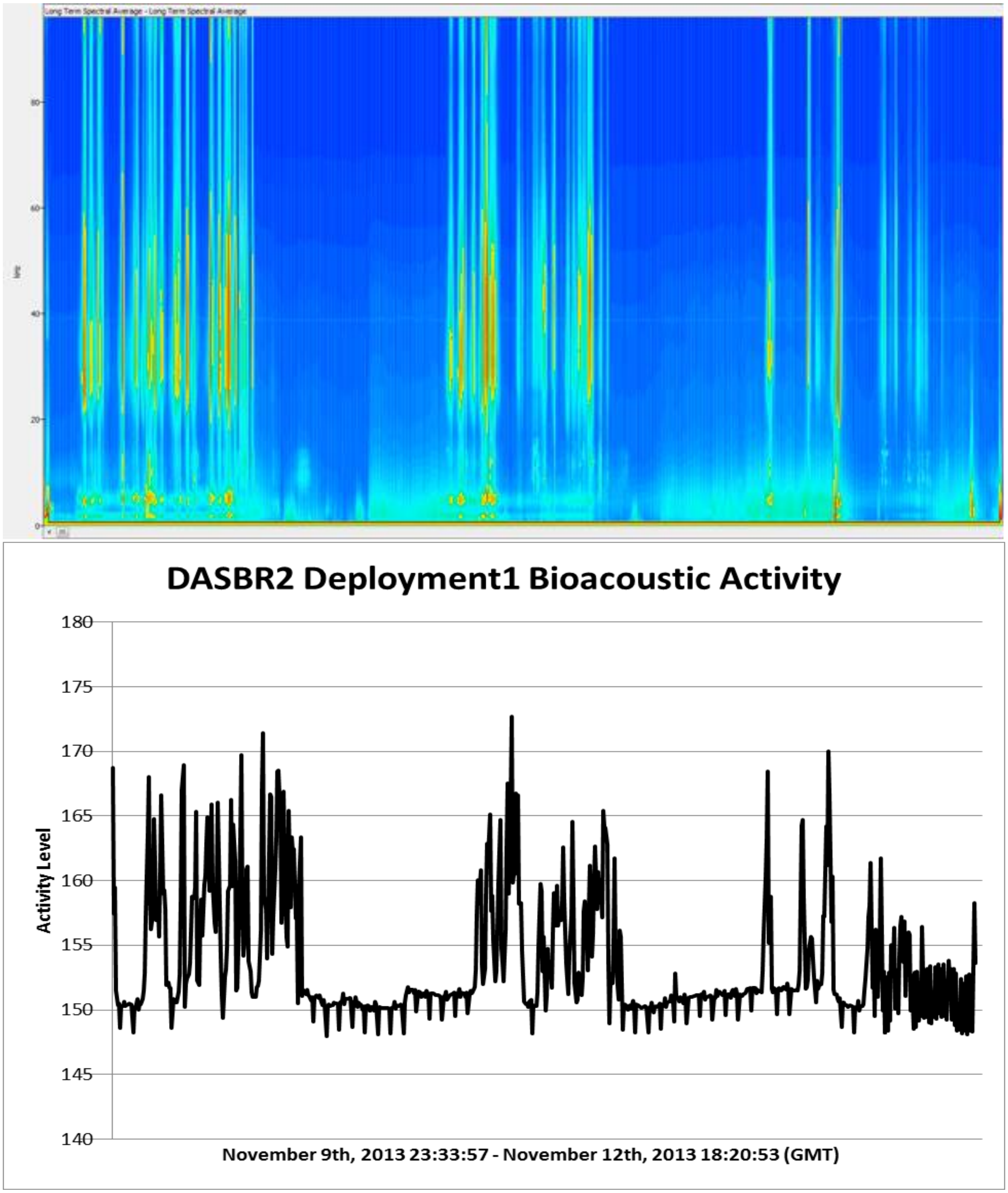


Figure 4. Example LTSA from PAMGuard and corresponding profile plot from ImageJ of DASBR2, deployment 1. All 6-minute samples above where an unscaled intensity threshold (>155 intensity in this plot) were considered to have bioacoustic activity. Pixel samples were averaged from 5-96 kHz to avoid vessel traffic noise interference.

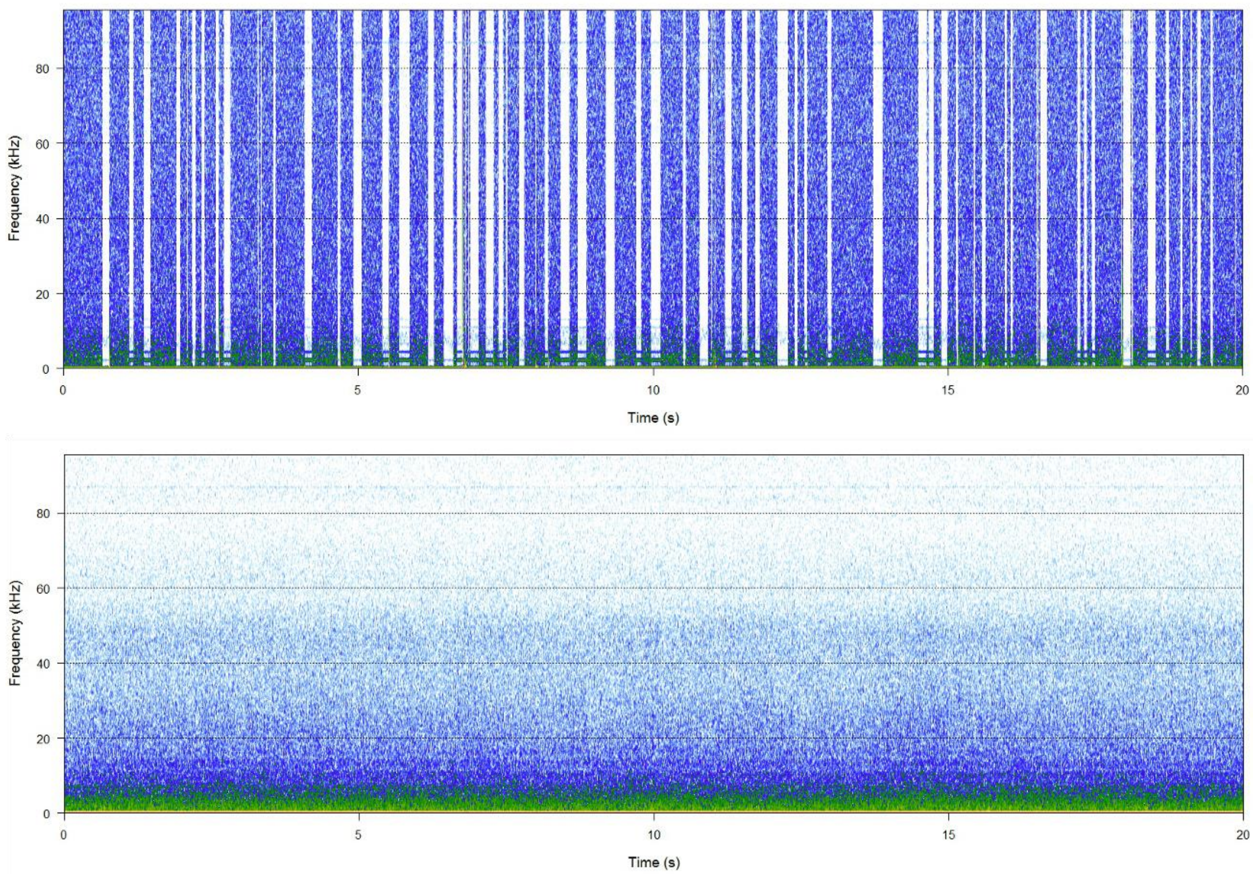


Figure 5. A 20 second spectrogram from file: DASBR0_20131118$233725, with the upper (top panel) and lower (bottom panel) hydrophones. Recorded during PAST 2013 during a time of low bioacoustic activity. Overlap=50%, FFT=1024. White vertical bands on the upper hydrophone indicate lost signals (drop-outs).

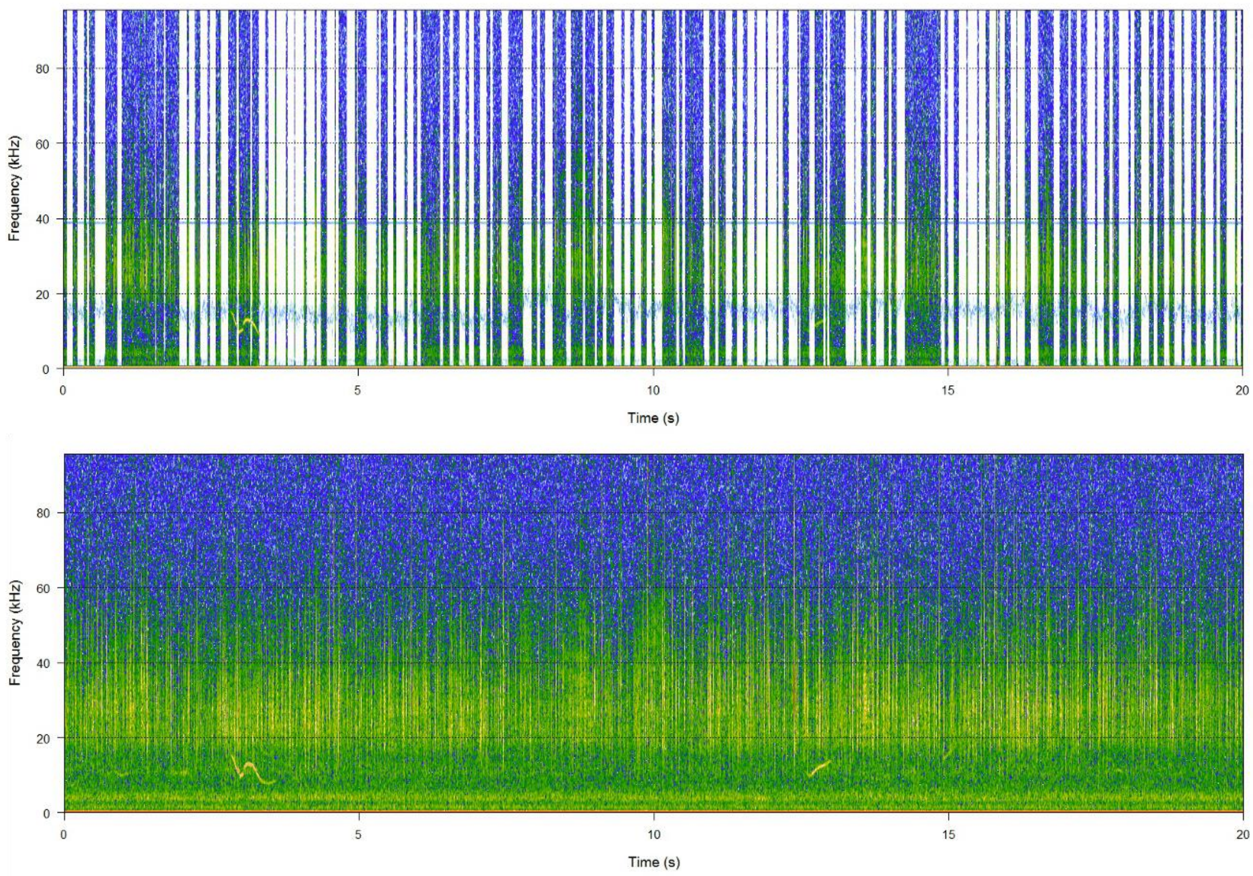


Figure 6. A 20 second spectrogram from file: DASBR2_20131121$023033, with the upper (top panel) and lower (bottom panel) hydrophones. Recorded during PAST 2013 during a time of high delphinid acoustics activity. Overlap=50%, FFT=1024. White vertical bands on the upper hydrophone indicate lost signals (drop-outs).

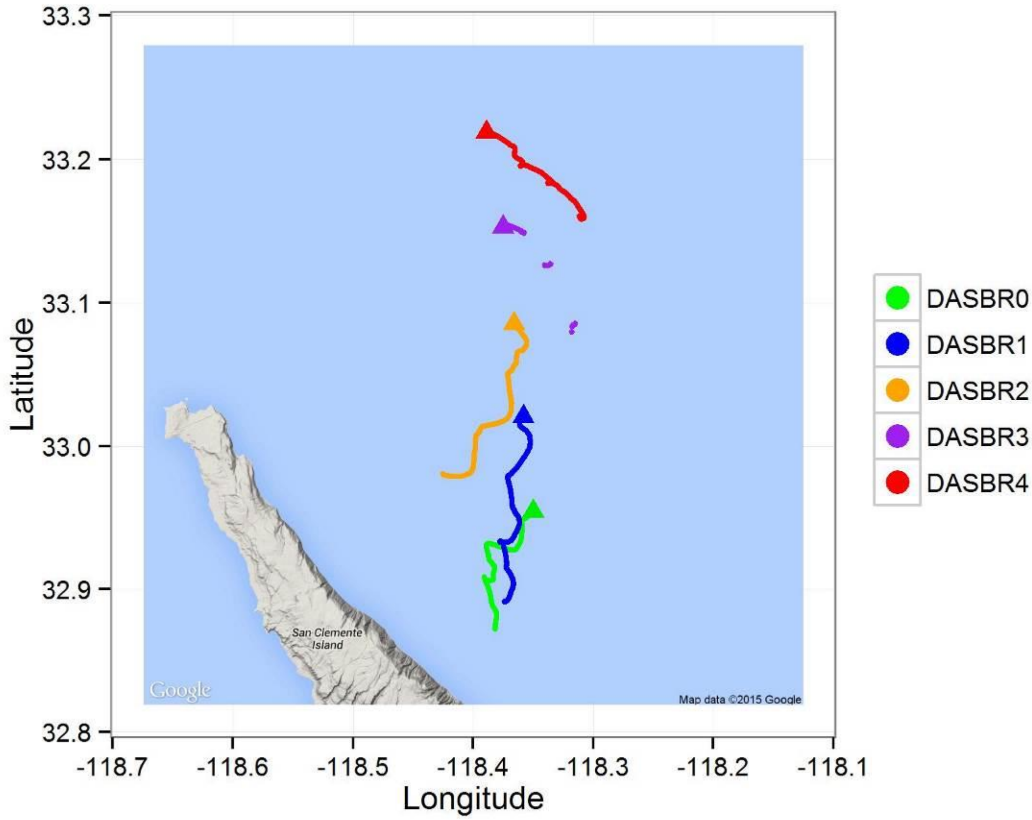


Figure 7. Drift paths of the five DASBR units for deployment 1. The starting point for all drift paths is marked with a triangle.

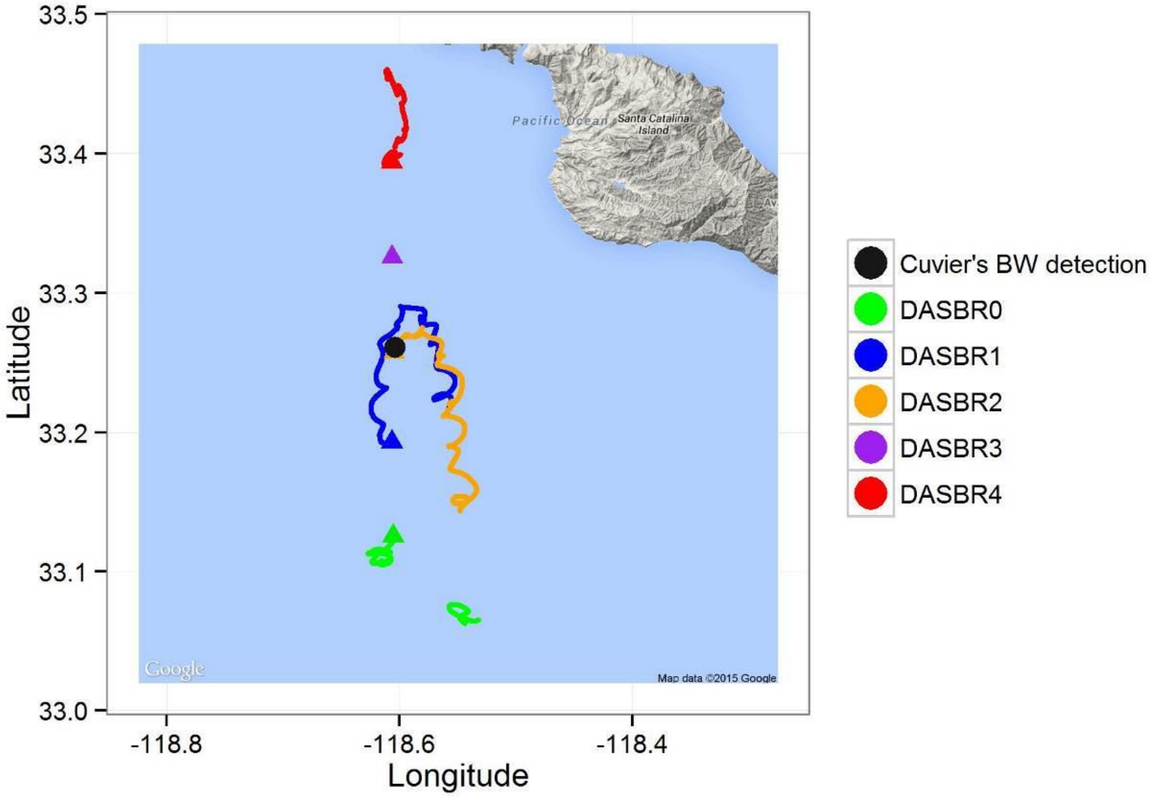


Figure 8. Drift paths of the five DASBR units for deployment 2. The starting point for all drift paths is marked with a triangle. The black point is a Cuvier's beaked whale detection.

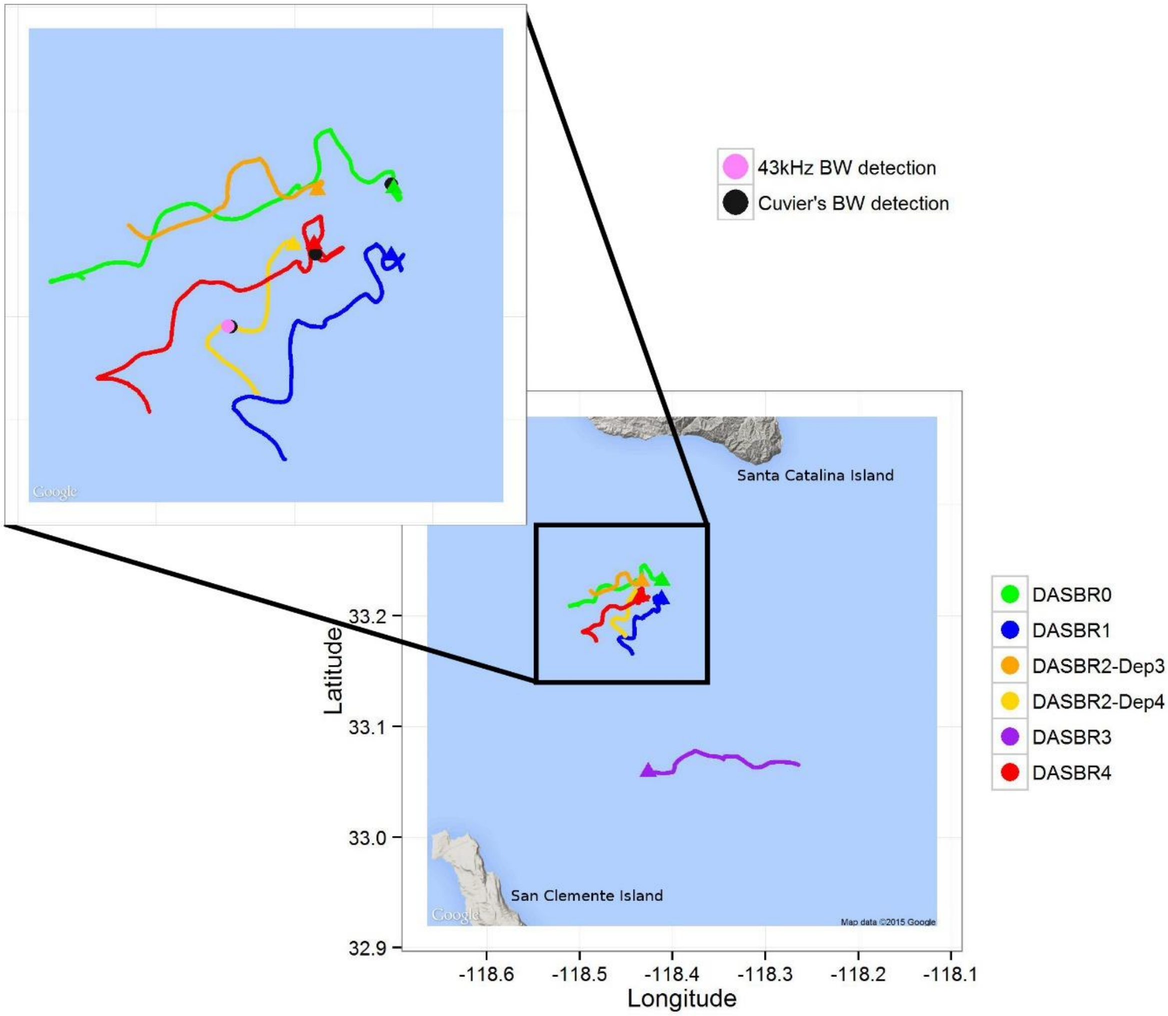


Figure 9. Drift paths of the five DASBR units for deployment 3, and deployment 4 for DASBR2. The starting point for all drift paths is marked with a triangle. The three black points are Cuvier's beaked whale detectors, and the pink is a 43 kHz beaked whale click train.

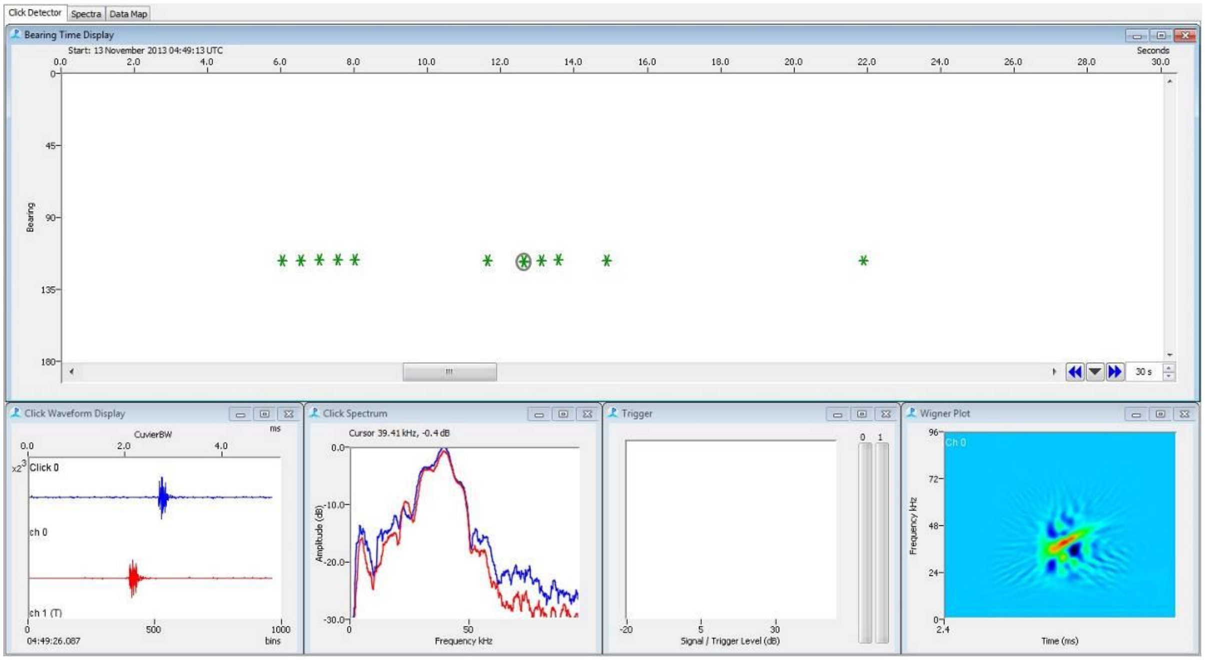


Figure 10. PamGuard software display of a Curvier's beaked whale detection on DASBR2 during deployment 2. Window includes a bearing time display for the detection, and waveform, spectrum and a Wigner plots of individual clicks. The trigger display is only used during initial click detection. The beaked whale producing this click train was deeper than 100 meters since the signal first arrived on the lower hydrophone (Click Waveform Display) and has a bearing greater than 90° (Bearing Time Display). For more information about these displays and how they are generated, please review the PamGuard manual.

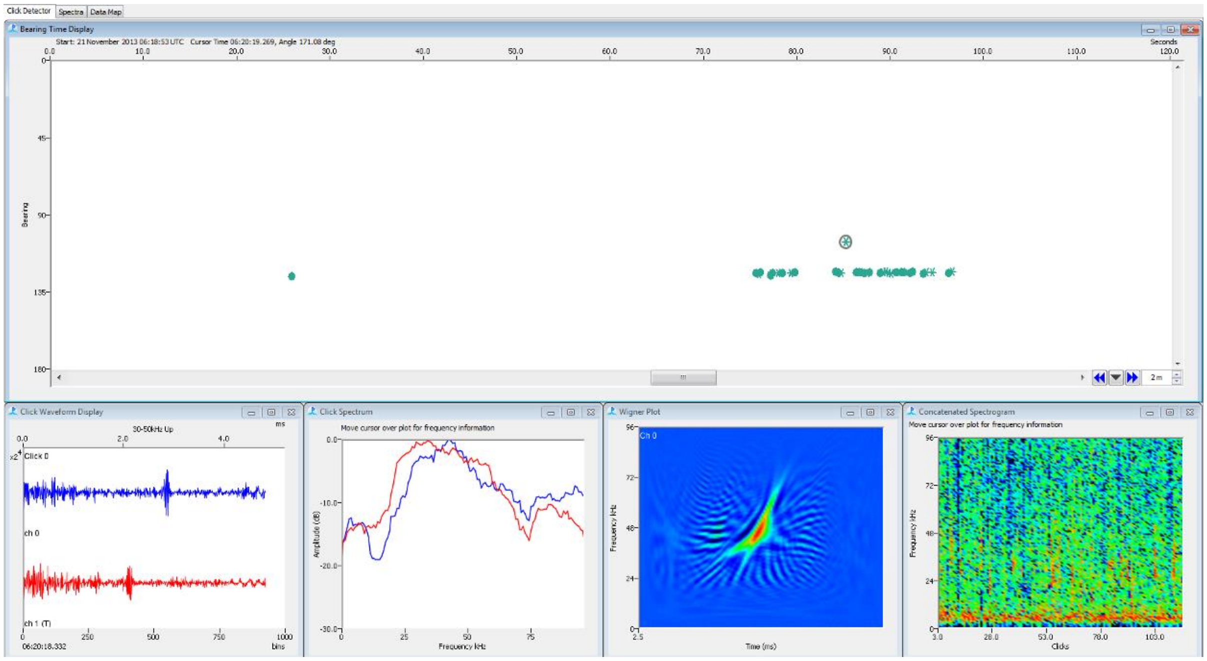


Figure 11. PamGuard software display of the 43 kHz beaked whale click train on DASBR2 during deployment 4. Window includes a bearing time display and concatenated spectrogram for the detection, and waveform, spectrum and a Wigner plots of individual clicks. For more information about these displays and how they are generated, please review the PamGuard manual.

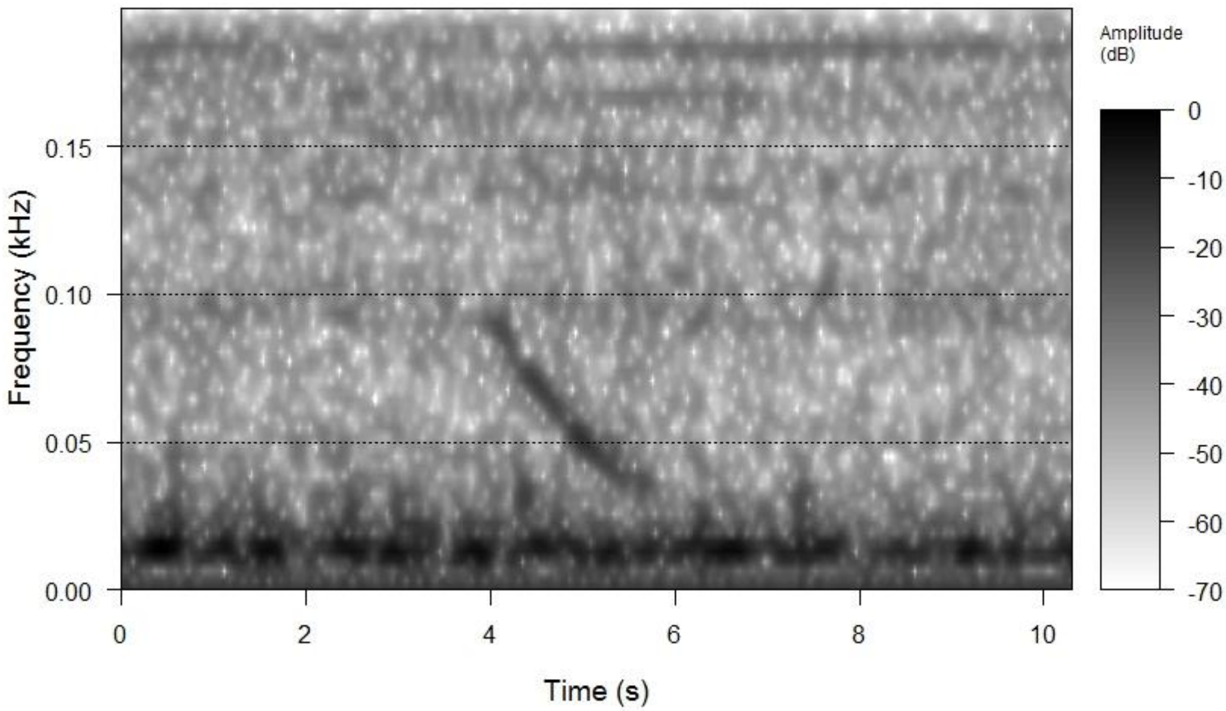


Figure 12. Example blue whale D-call recorded during PAST 2014. Overlap=85%, FFT=128.

Appendices

Appendix A. DASBR component list and cost for final design.

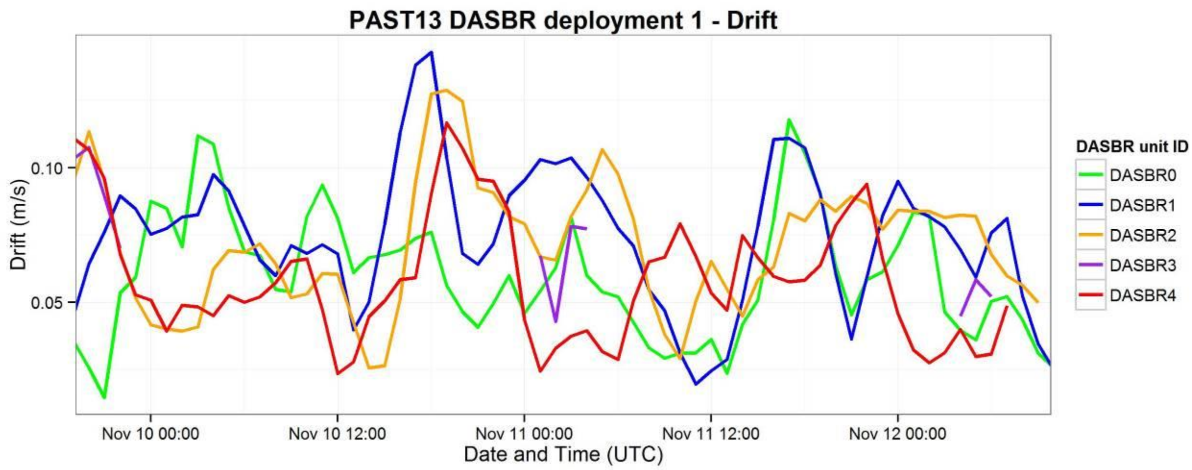
Item	Detailed Description	Unit Cost	Number	Total Cost
Recording system	Wildlife Acoustics SM2Bat+ w/ GPS option	$ 1,278.00	1	$ 1,278.00
Recording media	128 GB SDXC Memory Card	$ 169.00	4	$ 676.00
Underwater cable	ProPlex PPCat5eP 4 twisted pairs (110m=360ft)	$ 1.35	360	$ 486.00
Underwater connector	AK hydrovolt bulkhead BH-8A-MP	$ 94.00	1	$ 94.00
Underwater connector	AK hydrovolt bulkhead BH-8A-FS	$ 102.00	1	$ 102.00
Underwater connector	AK hydrovolt SS locking sleeves	$ 93.00	1	$ 93.00
Underwater connector	AK hydrovolt dummy plug DC-8A-FS	$ 24.00	1	$ 24.00
Underwater connector	AK hydrovolt dummy plug DC-8A-MP	$ 32.00	1	$ 32.00
Satellite locator	SPOT Hug satellite locator	$ 350.00	1	$ 350.00
Satellite locator	SPOT Hug annual subscription	$ 99.99	1	$ 99.99
Satellite locator	SPOT Gen3	$ 149.00	1	$ 149.00
Satellite locator	SPOT Gen3 annual subscription w/ unlimited tracking	$ 199.98	1	$ 199.98
VHF locator beacon	ATS VHF transmitter MM190B (164-166 MHz)	$ 163.00	1	$ 163.00
Hydrophones	HTI-96-min (20dB gain, 100 Hz high-pass, 3.3v)	$ 310.00	2	$ 620.00
Pre-amp	hydrophone differential pre-amps (parts only)	$ 30.00	2	$ 60.00
Depth sensor	Honeywell PX2AN1XX250PSACX pressure sensor (3.3v)	$ 84.69	1	$ 84.69
Anchor	Bruce anchor 1 kg (2.2 lbs)	$ 11.99	1	$ 11.99
Drouge	sea anchor 24" drouge	$ 14.00	1	$ 14.00
Lower buoy body	PVC pipe 4" x 48"	$ 24.51	1	$ 24.51
Upper buoy body	PVC pipe 6" x 18"	$ 20.00	1	$ 20.00
Coupler	PVC coupler 4"x6"	$ 21.44	1	$ 21.44
Lower end cap	PVC end cap 4"	$ 7.38	1	$ 7.38
O-ring lid	Sexton Co. acrylic door w/ double 0-ring w/ 6" PVC coupler	$ 200.00	1	$ 200.00
Elastic cord	5/16" polypropylene covered elastic cord (UV resistant) 50'	$ 0.56	50	$ 28.00
Polyurethane tubing	Ether-based clear polyurethane tubing (1"ID, 1.24"OD, 10')	$ 4.03	10	$ 40.30
	misc hardware	$ 200.00	1	$ 200.00
			Total	$ 5,079.28

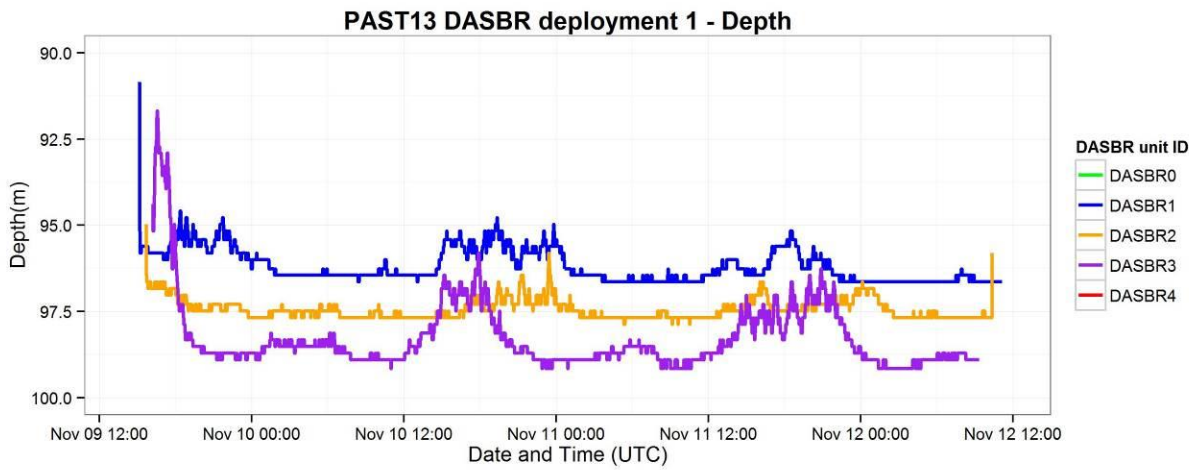
Appendix B. Deployment and Retrieval locations for the playback device provided by Aaron Thode used during Leg 2 of PAST 2013.

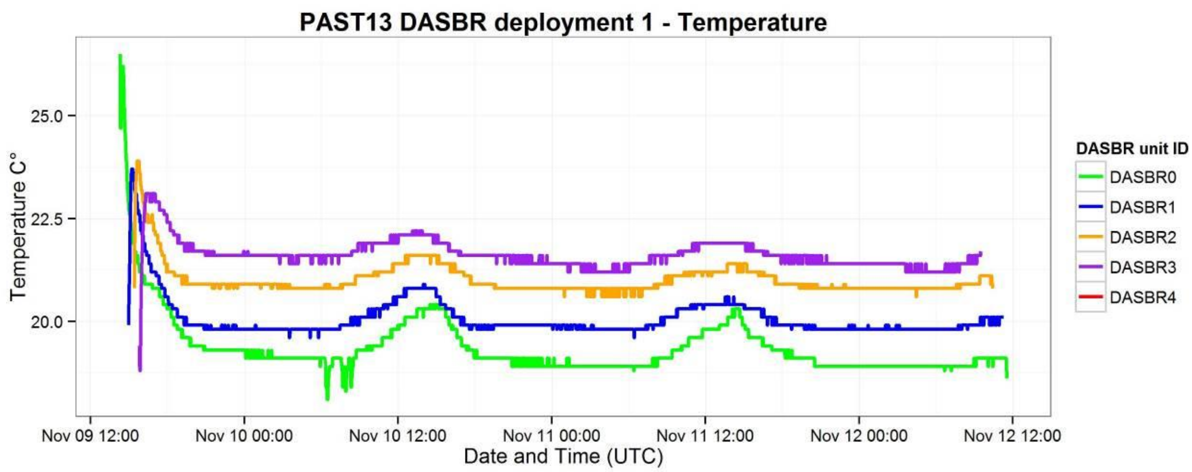
ID	Deployment	Latitude	Longitude	Retrieval	Latitude	Longitude
1	11/19/2013 0:21:22	33.21793	-118.42054	11/19/2013 0:31:25	33.21715	-118.42
2	11/19/2013 14:38:41	33.24052	-118.4241133	11/19/2013 14:53:00	33.24052	-118.424
3	11/19/2013 14:57:46	33.24052	-118.4241133	11/19/2013 15:08:09	33.24052	-118.424
4	11/19/2013 15:20:40	33.24052	-118.4241133	11/19/2013 15:32:13	33.24052	-118.424
5	11/19/2013 15:49:12	33.24052	-118.4241133	11/19/2013 15:59:56	33.24052	-118.424
6	11/19/2013 16:06:47	33.24052	-118.4241133	11/19/2013 16:18:15	33.24052	-118.424
7	11/19/2013 16:27:23	33.2116	-118.4076917	11/19/2013 16:40:54	33.21091	-118.405
8	11/19/2013 16:51:26	33.22851	-118.4100233	11/19/2013 17:01:02	33.2282	-118.407
9	11/19/2013 17:11:04	33.22784	-118.4269967	11/19/2013 17:22:27	33.22749	-118.424
10	11/19/2013 17:34:28	33.22765	-118.4476183	11/19/2013 17:45:58	33.22679	-118.445
11	11/19/2013 19:18:58	33.22459	-118.454055	11/19/2013 19:25:12	33.22405	-118.453
12	11/19/2013 19:29:54	33.22164	-118.445	11/19/2013 19:37:31	33.22101	-118.443
13	11/19/2013 19:42:13	33.21889	-118.4354383	11/19/2013 19:49:13	33.21825	-118.434
14	11/19/2013 19:57:21	33.21351	-118.41638	11/19/2013 20:09:22	33.21263	-118.413
15	11/19/2013 20:47:09	33.20815	-118.3970417	11/19/2013 20:58:17	33.20666	-118.393
16	11/19/2013 21:14:30	33.20695	-118.3927533	11/19/2013 21:21:32	33.20695	-118.393
17	11/19/2013 21:37:43	33.20695	-118.3927533	11/19/2013 21:45:58	33.20695	-118.393
18	11/20/2013 16:37:51	33.22849	-118.44833	11/20/2013 16:46:19	33.22849	-118.448
19	11/20/2013 16:56:10	33.21359	-118.4494633	11/20/2013 17:03:47	33.21367	-118.449
20	11/20/2013 17:14:19	33.19642	-118.45307	11/20/2013 17:23:54	33.1963	-118.452
21	11/20/2013 17:34:56	33.19421	-118.4247	11/20/2013 17:44:59	33.1947	-118.423
22	11/20/2013 17:52:13	33.20898	-118.4230083	11/20/2013 18:00:53	33.20931	-118.422
23	11/20/2013 18:13:27	33.21376	-118.4496167	11/20/2013 18:22:38	33.2137	-118.448
24	11/20/2013 18:34:16	33.21731	-118.473025	11/20/2013 18:45:02	33.21699	-118.471
25	11/20/2013 21:10:14	33.23152	-118.472775	11/20/2013 21:19:26	33.23047	-118.471
26	11/20/2013 21:26:27	33.22349	-118.4723333	11/20/2013 21:33:17	33.22262	-118.471
27	11/20/2013 21:39:44	33.21527	-118.4712267	11/20/2013 21:48:33	33.21421	-118.47
28	11/20/2013 22:07:13	33.21291	-118.503015	11/20/2013 22:13:35	33.21239	-118.502

ID	Deployment	Latitude	Longitude	Retrieval	Latitude	Longitude
29	11/20/2013 22:27:14	33.1984	-118.4695083	11/20/2013 22:36:33	33.19696	-118.468
30	11/20/2013 22:49:43	33.16499	-118.4646567	11/20/2013 22:59:40	33.16449	-118.462
31	11/20/2013 23:14:53	33.13185	-118.4593683	11/20/2013 23:22:32	33.1314	-118.457
32	11/20/2013 23:32:39	33.14842	-118.4624583	11/20/2013 23:41:29	33.14808	-118.46
33	11/20/2013 23:56:25	33.18185	-118.4666733	11/21/2013 0:04:28	33.18137	-118.466
34	11/21/2013 0:16:26	33.20654	-118.46994	11/21/2013 0:23:41	33.20598	-118.469
35	11/21/2013 0:38:01	33.20898	-118.5041017	11/21/2013 0:42:54	33.20876	-118.504
36	11/21/2013 0:57:43	33.23165	-118.4732217	11/21/2013 1:06:44	33.23143	-118.473

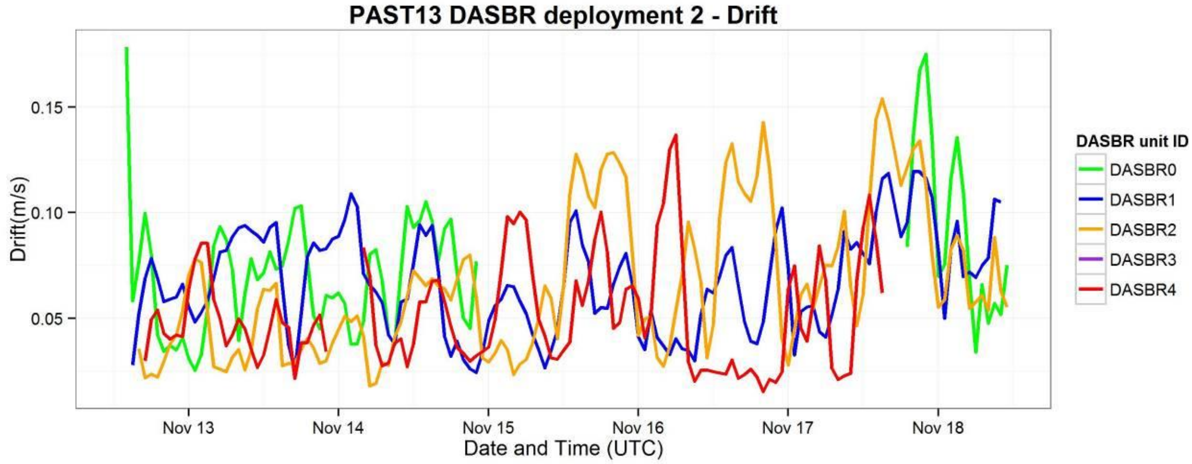
Appendix C. Drift speeds, array depth and surface temperature (inside the buoy) for PAST 2013, deployment 1.

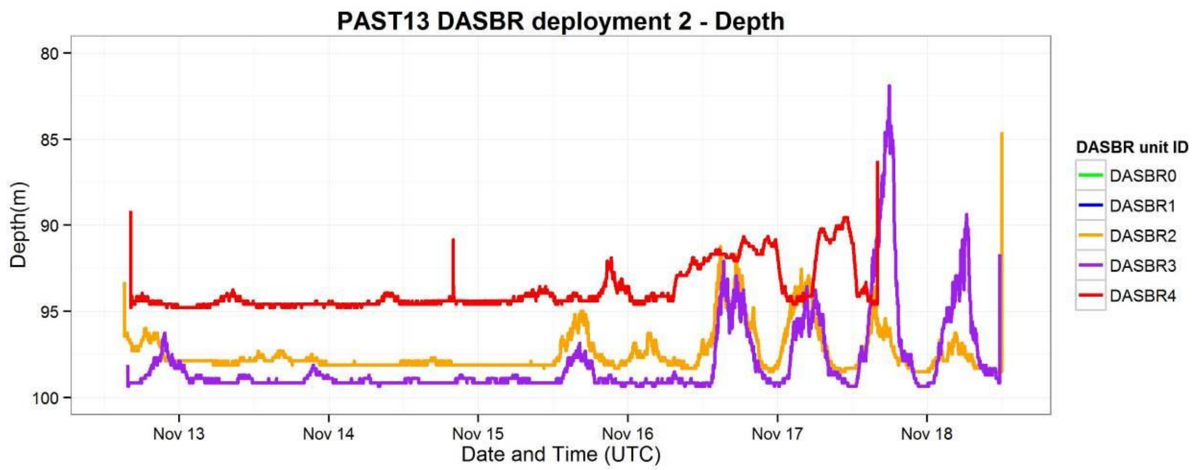


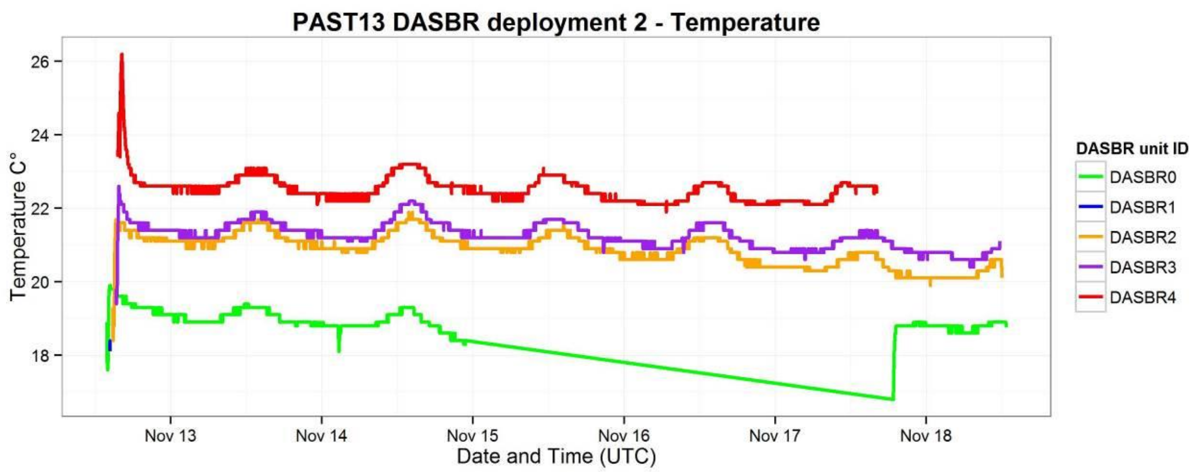




Appendix D. Drift speeds, array depth and surface temperature (inside the buoy) for PAST 2013, deployment 2.







Appendix E. Drift speeds, array depth and surface temperature (inside the buoy) for PAST 2013, deployment 3 (and 4 for DASBR2).